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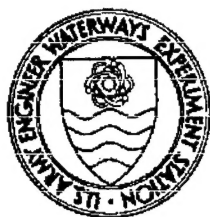
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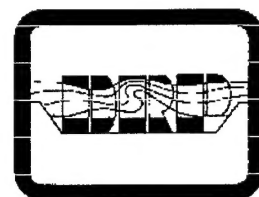
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# *Dredging Research Technical Notes*



## **Applying Ultrasonic Surface Detectors to Hopper Dredge Production Monitoring**

### **Purpose**

This technical note discusses the applicability of acoustic sensors for monitoring dredge draft and hopper bin water levels. It summarizes the testing and evaluation of acoustic sensors on the Corps of Engineers hopper dredge *Wheeler*.

### **Background**

Hopper dredges are used primarily to maintain navigation channels in marine environments. These dredges contain large onboard storage areas for holding the dredged material as the dredge operates. When the hopper is filled, the dredge travels to a designated disposal site, where the hopper load is released through doors in the bottom of the hopper or is pumped out. The load in the hopper can be measured by several methods. The load displacement meter is the standard method. Hydrostatic pressure change is determined through gas bubbler tubes fitted in the hull, bow, and stern of the dredge. This change in draft is related to the load in the hopper by the vessel load/displacement table which describes the vessel's draft as a function of vessel weight. The load data are recorded on a chart in the pilot house of the dredge in units of long tons versus time. These sensors are generally calibrated by the contractor who installed the system.

### **Additional Information**

Contact the author, Mr. Stephen H. Scott, (601) 634-4286, or the manager of the Dredging Research Program, Mr. E. Clark McNair, Jr., (601) 634-2070, for additional information.

## Introduction

Tests of acoustic sensors for measuring the dredge draft and depth of material in the hopper for production calculations were conducted on the hopper dredge *Wheeler* in July 1991 by personnel from the Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station (WES), for the Dredging Research Program. The *Wheeler* was dredging in the Mississippi River and off the coast of Galveston, Texas, during the test period.

The *Wheeler* primarily operates in the Gulf of Mexico, from the mouth of the Mississippi River to the Texas Gulf Coast. The *Wheeler's* hopper has a volume of approximately 6,023 cu m. Three dragarms are available for dredging, two 0.71-m-diam side dragarms and a 1.07-m-diam center dragarm.

## Sensor Description and Operation

The acoustic sensors used in the tests were rated for measuring distances up to 21 m. The transducers were about 0.45 m long and had approximately a 5.0-cm diameter (Figure 1). The 45-kHz operating frequency is high enough so that environmental noise around the hopper area generally does not interfere with the signal, but is low enough that temperature and density changes in the air can affect data.

The unit has 29 programmable modes. These modes set the range of measurement (minimum and maximum distances), calibrate the sensors, and specify input and output parameters. The units can also be used to control other remote functions based on sensor output. For example, when the unit senses a full hopper, a pump might be activated. A temperature sensor is incorporated into the unit to compensate for temperature

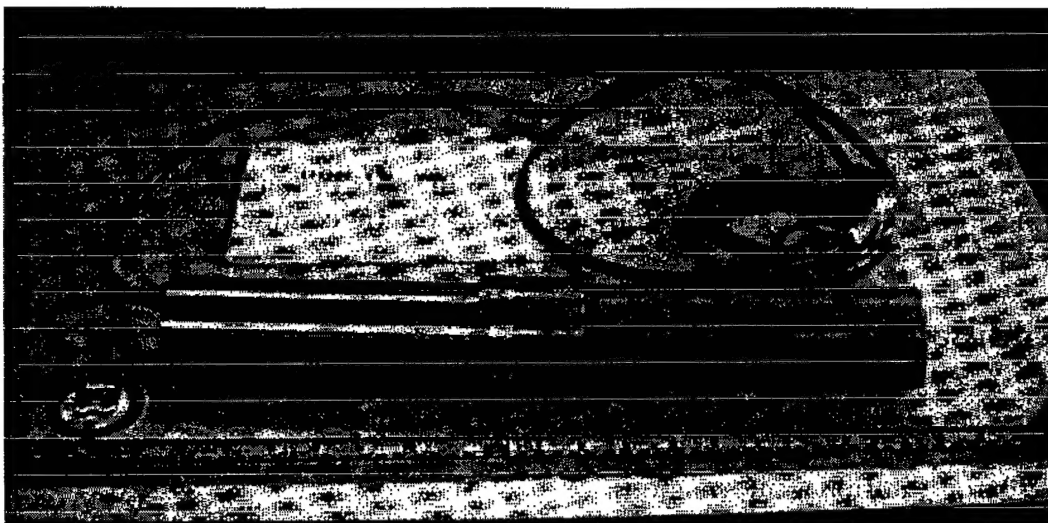


Figure 1. Acoustic sensor

changes. The dredging environment, especially in the hopper, frequently experiences high humidity as well as temperature fluctuation.

One very useful feature of the unit is the amplifier gain control. This feature can be used to amplify the desired acoustic signals and to eliminate the undesirable signals from environmental effects such as water vapor or signal reflections from objects in the path of the acoustic signal (for example, structural members in the hopper).

The accuracy of the sensor is reported to be 0.2 percent of the maximum range of operation. For this application, the maximum range was 12 m, with an accuracy of  $\pm 0.024$  m.

## **Sensor Calibration**

Before installation, the surface detectors were field calibrated. The detectors were positioned normal to a flat, smooth surface at a measured distance. The sensor output was observed and compared to the measured distance. If the sensor distance output was different from the measured distance, the output was corrected by inputting in the correct distance with the programmable modes of the sensor. This procedure was followed before the installation of both the hopper and draft sensors. After installation, the calibrations were checked by comparing the sensor output to soundings made with a tape measure.

## **Sensor Installation**

The draft acoustic sensors were mounted off the bow and stern of the *Wheeler* for determining the draft as a function of vessel weight (Figure 2). Sensors were mounted both port and starboard off the bow and stern to account for vessel motion. The data for the four draft sensors were averaged for the final draft calculation.

The hopper acoustic sensors were mounted fore and aft, as well as port and starboard, in the hopper for determining the depth of bin water in the hopper before dredging (Figure 3). The *Wheeler's* hopper contained many obstructions such as structural members and pipes that could potentially interfere with the acoustic signal transmission and reception. Locations were found that offered the most clearance for proper sensor operation. Data from the four hopper sensors were averaged for the final hopper depth calculation.

## **Average Density Calculation**

The draft acoustic sensors provide data on the load gain during dredging (hopper load as a function of draft), while the hopper acoustic sensors provide data on the depth of bin water in the hopper before it is filled.



Figure 2. Draft acoustic sensor located off *Wheeler* bow



Figure 3. Aft hopper acoustic sensor location

Draft data are compared to the load/displacement table of the dredge, which gives the displacement of the vessel as a function of load. The bin water occurs in the hopper due to the draft of the dredge. The volume of bin water as a function of depth in the hopper is determined from the dredge ullage table, which relates hopper volume to depth in the hopper. If the bin water density is known, the water weight can be calculated. The average density of the total load in the hopper is given by the following equation:

$$\rho_h = \frac{HOP_w + BIN_w}{VOL_h}$$

where

$\rho_h$  = average density of material in the hopper  
 $HOP_w$  = weight of slurry in the hopper  
 $BIN_w$  = weight of bin water  
 $VOL_h$  = hopper volume

## Data Acquisition

The acoustic transducers were programmed to continuously average the data over a 10-sec interval. Every 10 sec, the averaged draft and hopper depth data for each transducer were recorded on a personal computer through an RS-232 data interface. Software written by the WES Instrumentation Services Division converted the draft measurement to hopper load using the load versus displacement table for the *Wheeler* and converted the hopper depth measurement to hopper volume using the ullage table for the *Wheeler*. The software then calculated the average density in the hopper for the load (using the average density equation) based on a full hopper volume of approximately 6,023 cu m. This average density was then used to calculate the in situ cubic yards removed from the navigation channel. The acoustic transducer data were stored on the computer hard disk in binary format to optimize the storage capacity.

The acoustics data were taken for approximately two months during dredging in the Mississippi River just below Baton Rouge, Louisiana, and at Sabine Pass off the coast of Galveston Texas.

## Test Results

Figures 4 and 5 show acoustic draft and hopper depth data for the first six hopper loads taken from Sabine Pass on September 5, 1991. The loads are designated as L1 - L6 on the figures. The sediment at Sabine Pass consisted of fine silts, so no significant overflow of the hopper was permitted.

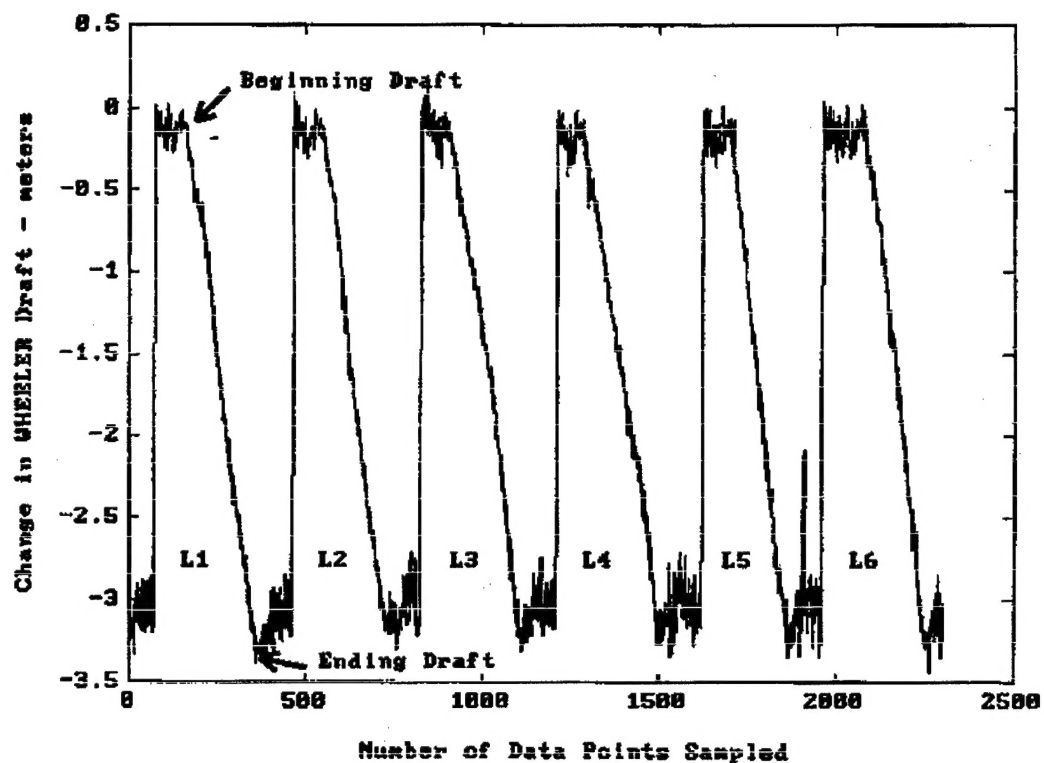


Figure 4. Draft acoustic sensor data

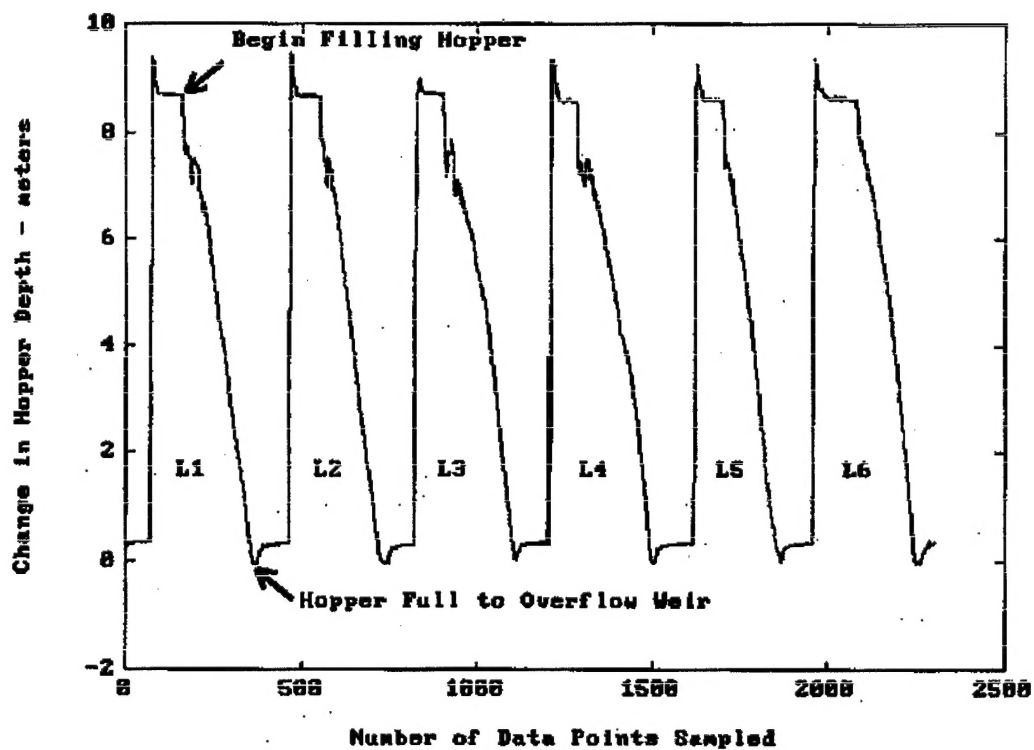


Figure 5. Hopper acoustic sensor data



Figure 4 gives the change in draft for each hopper load as a function of number of data points recorded. Each data point represents 10 sec of averaged data. At the top of the data record (beginning draft), the hopper is empty except for bin water. The dredge is not as stable when empty, resulting in more vessel motion. The acoustic sensors pick up this motion, as well as any surface wave action. As the dredge begins to fill, the vessel motion is damped, resulting in a cleaner data record. After filling is complete (ending draft), the sensors again see motion from the dredge traveling to the disposal site.

Figure 5 shows the change in hopper depth as a function of the number of data points recorded. At the top of the data record (begin filling hopper), the acoustic sensors detect the surface of the bin water in the hopper before filling begins. The hopper is filled during dredging up to the overflow weirs (hopper full to overflow weir). The total available depth in the *Wheeler* hopper for slurry was approximately 13.0 m (from the top of the overflow weirs to the hopper doors). By subtracting the change in hopper depth for a given load from the total depth available, the depth of hopper bin water before filling is determined. This figure is converted to volume with the vessel ullage table and, when multiplied by the density of the bin water, converted to weight.

Production data were collected for both coarse (sand) and fine (silt and clay) material dredging environments. The data records shown in Figures 4 and 5 represent dredging in fine sediments where overflow of the hopper is not permitted. The acoustic draft data for dredge operation in coarse sediments provided very good details of the overflow operation. Figure 6 shows five acoustic draft records for dredge overflow operations in a fine sand environment in the Mississippi River. The three stages of the dredging cycle are depicted with good resolution in Figure 6 (fill, overflow, and dump). The overflow sequence of the operation begins when

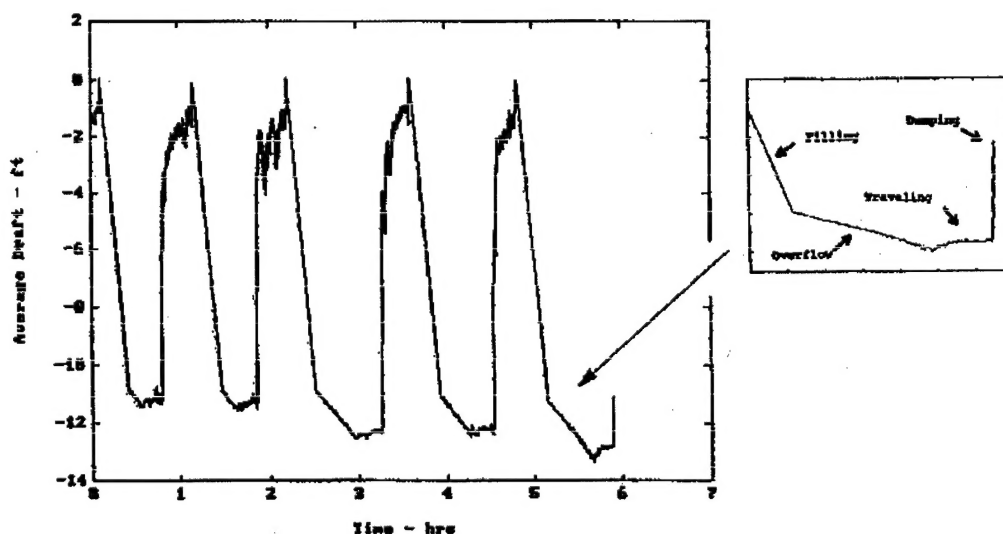


Figure 6. Acoustic sensor data for overflow operations



the slurry level in the hopper becomes higher than the four overflow weirs. The load gain after overflow begins is due only to solids retention in the hopper.

## **Conclusions**

The hopper acoustic sensors proved very dependable. As the hopper was filled, clouds of mist resulting from the high rate of slurry discharged into the hopper surrounded the adjacent area. Frequently, when dredging fine sediments, this mist contains clay that covers everything adjacent to the hopper. The hopper acoustic sensors were subjected to these conditions and maintained their calibration throughout the two months of testing. The data from the hopper sensors had good resolution, with minimal signal noise.

The use of these sensors for determining bin water load represents a significant increase in the efficiency of hopper dredge operations. The acoustic sensors can be interfaced with a chart recorder to provide a hard copy of bin water volume for every load, eliminating the need for personnel to monitor the bin water level.

The draft acoustic transducers also maintained calibration over the test period. They provided good resolution during the dredging cycle, particularly the overflow sequence.

The major problem with using acoustic sensors for draft measurement is the detection of vessel motion at the beginning and ending of the filling cycle. Accurate measurement of starting and ending draft are essential in measuring load. Wave action as well as vessel motion at these points resulted in data scatter of up to  $\pm 0.3$  m. Because the motion is somewhat random, smoothing the data through filtering or averaging routines may be difficult.

The advantage of using acoustic sensors for draft measurement is the ease of installation and servicing. The programmable modes allow the user to set up the sensor for specific operations and environments. These modes allow for temperature compensation, sensor calibration, maximum and minimum sensing distances for optimum signal resolution, and filtering background acoustic noise.

The draft sensors can be located in accessible areas, so that a malfunctioning sensor can easily be replaced without a major time-consuming effort that can delay dredge operations. The sensor may be calibrated by operating the sensor at a known distance and setting this distance using the programmable modes of sensor operation.